**Abstract**

*Pistia stratiotes* L. commonly known as water lettuce belongs to Araceae. It has been used in various medicines for the

treatment of eczema, leprosy, ulcers, piles, stomach disorder, throat and mouth inflammation, a few to mention. This review

article is a compilation of the updated information regarding phytochemical, pharmacological, medicinal, bioremediation

potential, allelopathy, utilization and management of water lettuce. In Pakistan it was first reported from Razmak, South

Waziristan in 1972, but now it is widespread throughout the country. Information regarding the uses and effects of different

extract (ethanolic and methanolic) of this plant is also documented. *Pistia stratiotes* possess different useful activities like,

diuretic, antidiabetic, antidermatophytic, antifungal, and antimicrobial properties against harmful diseases. It has great

potential for absorption of heavy metals (Fe, Zn, Cu, Cr, and Cd) without developing any toxicity or reduction in growth due

to metal accumulation and has shown a wide range of tolerance to all the selected metals and therefore can be used for water

purification and to combat water pollution in waste water bodies such as drainage ditches and channels carrying industrial

effluents*.* This article provide bases and encourages further study on any of the above mentioned aspects of *P. stratiotes* for

creation as well as confirmation of the information and also to reveal therapeutic effects, bioremediation and

bioaccumulation potential with possible isolation of active bio-moieties and their mechanism of action.

**Introduction**

*Pistia stratiotes*, also known as ‘Jal kumbhi’, water

cabbage, water lettuce, Nile cabbage, or shellflower is a

free floating aquatic plant of streams, lakes and ponds.

Due to its stoloniferous nature it is always found

anchored to the hydrosoil when the water level recedes

and in marshland conditions and loves alkaline/lime-rich

water. *P. stratiotes* belongs to arum/ Araceae family

(Quattrocchi & Umberto, 2000). As a floating weed it

forms dense mats on surface of water bodies, disrupting

aquatic flora and fauna underneath and thus adversely

affects the water ecosystem and hinders water flow,

fishing, swimming, boating, water sports and navigation

(Attionu, 1976; Holm *et al*., 1977; Bruner, 1982;

Sharma, 1984). It lowers available oxygen and pH of

water and thus damages rice crop when enters into

paddy fields, develop roots in the soil and competes with

crop under shallow water conditions (Hussain *et al.,*

2000). It replaces the native hydrophytes in ponds and

other water reservoirs (Marwat *et al*., 2010). The plant

serves as a preferred host for mosquitoes, vectors of

malaria, encephalomyelitis and rural filariasis. The

Anopheles mosquito, which carries the parasite

responsible for malaria, is frequently associated with *P.*

*stratiotes* because the hydrophyte provides suitable

shelter and breeding site (Holm *et al.,* 1977). Being a

serious weed in more than 40 countries (Holm *et al*.,

1979), it is used as feed for swine as well as buffalos

(Mukhtar & Hafiz, 2001). Similarly a large number of

medicinal and other uses are attributed to *P. stratiotes*

which makes it a very special plant to be exploited

(Kirtikar & Basu, 2001). Recently spread disease like

dengue, causeb by mosquitoes may also rely on this

plant but further studies are needed.

The recent upsurge in herbal medicines has made it

possible to transform traditional medicine into a modern industry to deliver healthcare to the common man (Joseph

& Justin, 2011). This revival of interest in plant derived

drugs is mainly due to the current widespread belief that

“green medicine” is safe, and clinically effective, better

tolerated by patients, less expensive and globally

competitive (Epko *et al*., 2011; Pradhan *et al*., 2009).

Looking to *P. stratiotes* from medicinal point of view it is

used as antiseptic, antitubercular and antidysentric. Its

extract is used as an anodyne for eyewash and for

relieving ear complaints. Its ash is applied to scalp for

curing ringworm. Leaf extract is used in eczema, leprosy,

ulcers, piles, and syphilis. Leaf extract boiled in coconut

oil is applied to the skin in chronic dermatitis (Kirtikar &

Basu, 2001). Its concoction is useful for relieving nervous

disorders, fever and intestinal bacterial infections. *P.*

*stratiotes* is useful in the treatment of stomach disorder,

throat and mouth inflammation (Mukhtar & Tukur, 2000).

It was reported that ethanol and hot water fractions of the

plant exerts antimicrobial action on a few pathogenic

bacteria while chloroform fraction of the same plant

possess both antifungal and antibacterial activities on

some pathogens (Mukhtar & Huda, 2003).

Water lettuce is capable to remove nutrients and

heavy metals from the sewage sludge and drainage

ditches. It is the most suitable plant for waste

phytoremediation in tropical areas. Fonkou *et al*., (2002)

reported that the physicochemical parameters reduce

progressively from the influent to effluent ponds like

turbidity, phosphates, total iron, sulfates and suspended

solids. The improper sewage disposal is a big

environmental concern which is impossible to solve with

conventional methods as these methods are expensive and

labour intensive. Waste disposal is a major concern in

developing countries like Paksitan. The only solution is to

devise a system based by using aquatic plants to treat

wastewater, as suitable alternative which is cost-effective

and safe to treat sewage (Reddy & Smith, 1987; Cooper

& Findlater, 1990). This paper highlights the importance

of *P. stratiotes* as a medicinal plant, its utilization for the

benefit of the society, and how to manage it where it has

become a noxious weed.

The most ideal condition to avoid *P. stratiotes* will be

to prevent the introduction of water lettuce; which

requires a lot of awareness on the part of the state as well

as public (Pheloung, 1995). However once the infestation

occurs then any of the control method should be adopted

which best suits the situation alone or in combination with

each other as integrated weed management approach.

Since it is a perennial weed of rice, therefore integration

of crop rotation, puddling and use of rice herbicides can

effectively control the weed (Marwat *et al*., 2010).

Several researchers (Shehzad *et al.,* 2013; Usman *et al.,*

2013) have reported the importance of weeds and their

potential disadvantages. The most common physical

control method is raking or seining it (using a large

fishing net) from the pond’s surface. Raking can be done

by using mechanical harvesters. The plant is then

removed from waterways to the shore where it is cut up

by chopping machines and disposed of by spraying across

the water (Ramey, 2001). Chemical control methods that

have been successful in treating *P. stratiotes* include the

herbicide endothall, which can act quickly and kill all

plant cells that it contacts. However, water lettuce has

also been effectively and completely controlled in many

countries by the leaf-feeding weevil, *Neohydronomus*

*affinis* under laboratory conditions. In a field study in a

drainage ditch with highly eutrophic conditions the weevil

controlled the thick mats of the water lettuce completely

to 0.5% in a single season. The plant is affected in all

respects from control point of view (Moore, 2005). The

paper explores medicinal, bioremediation potential with a

touch of management strategies of water lettuce and

provides a launching pad for further study in this regard.

**Distribution**

Water lettuce is widely distributed in Pakistan in

reservoirs, ponds, marshy areas, lakes and stagnant water

bodies (Marwat *et al*., 2010). Being an exotic plant; the

exact way and time of its introduction to Pakistan is

unknown, but according to Stewart (1972), it was first

time reported from Razmak, South Waziristan, Pakistan

but now it can be found countywide up to 2500 meter

altitude. Fawad *et al*., 2013 reported that *P. stratiotes* L.,

was the most problematic and abundant weed in all

habitats and water bodies of Swabi district of Khyber

Pakhtunkhwa. On world level it is one of the most widely

distributed hydrophytes in the tropics. It was first

discovered from the Nile and presently it occurs in nearly

all fresh bodies in tropical and subtropical regions.

According to Holm *et al*., (1977) it has a cosmopolitan

distribution and is considered indigenous in South and

Central America, Africa and South-East Asia. It was

introduced into Australia some 50 years ago. Gillet *et al*.,

(1988) are of the opinion that it is indigenous in the

Northern Australia, where its natural enemies are

regulating its population and has not been recorded at

nuisance levels in this area, which creates the possibility

that this area might be native for this plant.

MUHAMMAD AZIM KHAN *ET AL*.,

The widespread distribution in most countries might

be due its medicinal use or fodder for cattle and pigs

(Sculthorpe, 1971). Its growth is limited by low

temperatures (Small, 1933; Muenscher, 1967; Wiggins,

1980). However, scattered ephemeral populations have

been reported from some colder climates (Dray & Center,

2002) where it acts as annual and rely on germination

from seeds and on re-introductions; often discarded from

aquarium in water bodies (Pieterse *et al*., 1981). *P.*

*stratiotes* occurs in the Nile Delta in Egypt, but due to

colder climate it does not attain the status of a major

aquatic weed as compared to tropical conditions

(Tackholm, 1974). Nile river studies indicated presence of

herbivores in Southeast Asia (Habeck & Thompson 1997)

and medicinal use in India and southern Asia (Stoddard,

1989; Tripathi *et al*., 2010). Documented introductions

and its non-native status are confirmed for Southern

Australia and New Zealand (Waterhouse, 1997) remote

islands of the tropical Pacific (Fosberg *et al*. 1987),

Slovenia (Sajna *et al*., 2007) and southern Idaho (Howard,

2010). Water lettuce’s over growth make it invasive

species (Holm *et al*., 1977). This weedy habit and bio

geographic ambiguity have together made this plant a

classic example of a cryptogenic species in many areas of

the world (Rana & Ranade, 2009).

In Pakistan, *P. stratiotes* is wide spread and is found

everywhere in almost all aquatic bodies. While in Khyber

Pakhtunkhwa province, this weed is a major aquatic weed

in all distracts and so far there is no use of this plant. It

seems that there is a great potential to use this weed as

medicine, fertilizer and for phytoremediation. However,

detailed studies that address all the possible uses needs to

be explored.

**Botanical description:** *Pistia stratiotes* L*.*, is a freefloating

aquatic plant with sessile leaves forming a

rosette. The leaves are pale-green, 10-20 cm long and 10

cm wide, spathulate to obovate with a rounded to truncate

apex. Around 7-15 veins run parallel from the base. The

lower surface is covered with whitish hairs (Cook *et al*.,

1974; Aston, 1977; Holm *et al*., 1977; Sainty & Jacobs,

1981). Inflorescence is axillary, solitary, spathulated with

a single pistillate flower at base, and 2-8 staminate

flowers above. Flowers are unisexual, staminate with two

stamens, pistillate with unilocular ovary having numerous

ovules, a slender style and penicillate stigma, the fruit

with many thin seeds (Acevedo-Rodriguez & Nicolson,

2005). Its seeds germinate on the hydro-soil and float to

the surface within 5 days. Germination can also occur in

the dark. *P. stratiotes* does not survive freezing

temperatures. Germination does not occur below 20°C. It

flowers in summer and give fruits at the end of hot season

(Chadha, 1998). The seeds float on the surface for few

days, transported by currents and water fowl, before they

sink to the bottom (Holm *et al*., 1977). *P. stratiotes* varies

largely owing to the influence of environmental factors.

**Habitat:** *Pistia stratiotes* is an aquatic plant, weed of

stagnant water, can be more problematic in rice in the

future (Marwat *et al*., 2010). It grows in a very wide

variety of aquatic habitats. It requires a moist habitat,

founds in lakes and rivers but prefers relatively stagnant

*PISTIA STRATIOTES*: PHYTOCHEMISTRY, USES AND MANAGEMENT OPTIONS

water. It can survive terrestrial condition by anchoring to

the hydro-soil for a few weeks when the water level

recedes. It is very sensitive to frost; the best range of

temperature is 15-35°C (Rivers, 2002). It has a low

salinity tolerance; salt concentrations of 1.66% are toxic

to the plant (Haller *et al*., 1974).

**Phytochemistry:** *P. stratiotes* plant extracts consist of

various alkaloids, glycosides, flavonoids and phytosterols.

Leaf and stem extract consist of 92.9% H2O, 1.4% protein,

0.3% fats, 2.6% carbohydrates, 0.9% crude fiber and 1.9%

minerals (mostly potassium and phosphorous). Leaves are

rich in vitamins A & C, stigma-sterol, stigma-steryl,

stigma-sterate and palmitic acids are found in abundance.

2-di-cgl-cosy-flavones of vicenin and lucenin type,

anthocyanin cyaniding-3-glucoside, luteolin-7-glucoside

and mono-C-glcosyl flavones–vitexin and orientin have

also been isolated from the plant (Khare, 2005). Stratioside

II (a new C13 norterpene glucoside) is the major

component of this plant. Leaves are rich in proteins,

essential amino acids, stigmatane, sito-sterol acyl

glycosides and minerals (Ghani, 2003). Vicenin an

anticancer agent (Nagaprashantha *et al*., 2011) and

cyanidin-3-glucoside (an anthocyanin) is present (Rastogi

& Mehrotra, 1993). Aliotta and Monaco (1991) isolated

sitosterol acylglycosides; phytosterols from the ethereal

extract of *P. stratiotes*. The plant contains large amounts of

di-c-glycosyl-flavones similar to vicenin and lucenin and

their derivatives, traces of anthocyanin; cyanidin-3-

glucoside and a luteolin-7-glycoside, mono-cglycosylflavones,

vitexin and orientin (Zennie & McClure,

1977). Using column chromatography resulted in isolation

of stigmastanes as well as eight new compounds as

Ergosta-7, 22-diene-3,5,6-triol, 7-hydroxyl-sitosterol,

sitoindoside, soya-cerebroside, luteolin, chrysoeriol 4-*O*-Dglucopyranoside,

sitosterol and daucoterol (Liu *et al*., 2008;

Monaco, 1991). The flavonoid chemistry of *P. stratiotes*

shows an evolutionary link between the aroids and the

lemnaceae due to similar biochemical pathways to most

flavonoids, which strengthens the concept that lemnaceae

may have arisen from a *Pistia*-like ancestor (Zennie &

McClure, 1997). *P. stratiotes* can be used as a model plant

in biochemical study of oxalic acid formation and calcium

regulation as related to calcium oxalate production in pure

cultures (Tarlyn & Kotsman, 1998).

**Utilization of *Pistia stratiotes***

**Biogas production:** *Pistia stratiotes* can be utilized as a

substrate for biogas production in batch digestion. With

inoculation, a high rate of biogas can be sustained for

nearly 10 days with an average 58-68% methane

production and significant concentrations of propionic,

butyric, isobutyric, valeric, and isovaleric acids. These

acids are present only in detectable concentrations during

the first 4 days. The addition of inoculum improves the

performance significantly (Abbasi & Nipaney, 1991). It

can be exploited for bio-fuels through GM bacteria;

consequently this will help in managing the weed,

mitigating water pollution, relieving energy problems and

protecting the aquatic ecosystem (Julias *et al*., 2012).

**Role in water purification:** *Pistia stratiotes* L. is a

‘hyperaccumulator’ by removing heavy metals, organic

compounds and radio-nuclides from water (Sinha *et al*.,

2006). It purifies the polluted aquatic system from

detrimental metals. Application of plants for remediation

of contaminated soil and aquatic system is increasing due

to its low cost and lesser harmful effects than any other

method (Ignjatovic & Marjanovic, 1985; Reddy &

DeBusk, 1986; Prasad & Freitas, 2003). Lower size of the

plant for removal of heavy metals is a credit for this plant

as compared to water hyacinth (Quinones *et al*. 2006;

Sinha *et al*. 2009; Mufarrege *et al*. 2010; Singh and Sinha

2011). It can be used for Zn extraction from industrial

wastes as it has strong affinity to Zn absorption in an ecofriendly

manner (Nurhayati *et al*., 2012). The same is true

about mercury too (Skinner, 2007). The accumulation of

heavy metals like Fe, Zn, Cu, Cr, and Cd does not cause

any toxic effect on the plant which qualifies the plant to

be used for the phyto-remediation of waste water for

heavy metals on large-scale (Mishra *et al*., 2008). It has

been considered a promising plant for the remediation of

contaminated waters (Maine *et al*., 2001).

Gujarati *et al*., (2005) reported that the fate of

antibiotics used in US in feed for livestock is their presence

in our food. They enter to waste water streams from

feedlots and farmyard manure. Microbes in the water

bodies are predisposed to develop resistance in these

antibiotics; producing resistant human pathogens causing

severe diseases. Phyto-remediation of these antibiotics is a

useful tool to resolve the issue. Water lettuce gave high

antibiotic modification rates through root exudates

tetracyclines and oxy-tetracyclines; the two frequently used

antibiotics in veterinary feed and medicines. *P. stratiotes* is

best candidate for in situ bioremediation of drug

contaminated water body as it is more sensitive than the

other aquatic plants tested. Thus it is recommended for

quinolone bioremediation but less effective for sulfonamide

(Forni *et al*., 2006).

**Biological and pharmacological activities:** *In vitro* free

radicals cause tissue injury and consequently cause many

diseases like arthritis, hemorrhage, arteriosclerotic

vascular disease, diabetes, hepatitis etc. *Pistia stratiotes*

leaves extract is capable to reduce superoxides and nitric

oxide radicals and to lower free radical induced cell

injury. The ethanolic extract of this plant leaves inhibits

the enzyme xanthine oxidase and hence uric acid

formation, the xanthine oxidase inhibitor is used in the

treatment of gout (Jha *et al*., 2010). The antipyretic nature

of the extract can be utilized for treating fever (Kumar *et*

*al*., 2011). The leaves are used as disinfectant and for the

treatment of tuberculosis, dysentery, eczema, leprosy,

ulcer, piles, syphilis and parasitic worms (Anon., 1999;

Kumar *et al*., 2010). The ash of water lettuce is used for

curing tinea. Egami *et al*., (1998) reported the

antibacterial activity in the plant. *P. stratiotes* works as

antioxidant (Thuong *et al*., 2006), bronchodilator (Achola

*et al*., 1997), antitumor (Fatope *et al*., 1993), antifungal

(Premkumar & Shyamsundar, 2005), diuretic (Pallavi *et*

*al*., 2011), antiprotease (Jedinak *et al*., 2010), emollient

(Tripathi *et al*., 2010), antidiabetic (Joy *et al*., 2001) and

antimicrobial (Abu Ziada *et al*., 2008). Kumar *et al*.,

(2010) studied the ethanolic extract of *Pistia* against

human parasitic worms in comparison with the standard

medicines like piperazine citrate and albendazole and

found that the extract was as useful as the standard drugs.

**Anti-inflammatory activity:** Anti-inflammatory herbal

medicine with low side effects is much valued (Tripathy

*et al.*, 2010). Water lettuce is traditionally used for curing

opthalmia and iritis in Ghana, due to its analgesic antiinflammatory

effect (Abbiw, 1990; Arber, 2002; Tripathi

*et al.*, 2010; Kumar, *et al.,* 2011). Its water and ethanolic

extracts given in acute inflammation relieve hyperalgesia

by inhibiting the chemicals (histamine, serotonin,

prostaglandin, and bradykinin) that stimulates and

sensitizes the nociceptors (Koffuor *et al*., 2012). The

phytochemical screening revealed presence of some

flavonoids and sterols, which might be the source of the

anti**-**inflammatory activity of this plant (Pelzer *et al*.*,*

1998; Funakoshi *et al.,* 2011). The sterols have structural

resemblance to steroids and are known to soothe irritation

(Mencarelli *et al*.*,* 2009).

**Diuretic activity:** Pallavi *et al*., (2011) reported

antidiabetic and diuretic activities in the leaf extracts of

water lettuce. They found that oral administration of the

extracts produced significant diuretic action which might

be its ability to block sugar absorption. The diuretic

activity of ethanol leaf extract of *Pistia stratiotes* was

proved very effective in the laboratory trials on albino

rats. The extract increased the bulk of urine and regulated

the balance of electrolytes depending on dose and time

interval between doses. The results revealed that ethanol

leaf extract of this plant has significant diuretic activity,

and supports the traditional practice of using water lettuce

as diuretic (Sahu *et al*., 2009).

**Antifungal activity:** Dermatophytes

are fungi that affect

the keratinous tissue (hair and nails) causing superficial

infections (Conant et al., 1991). Natarajan et al., (2003)

found that P. stratiotes methanolic extract was most

effective against dermatophytes. The antifungal activity

of water lettuce justify its use for curing different diseases

with fungal or fungal-like symptoms, like ringworm

infection of the scalp, syphilitic eruptions, skin infections,

boils, and wounds, and highlight the worth of indigenous

knowledge of ethno-botany in choosing water lettuce to

discover new medicines. Further research is required to

investigate the biochemicals responsible for the antifungal

activity of this plant (Kirtikar and Basu, 2000;

Premkumar & Shyamsundar, 2005).

Anti microbial activity: In agriculture and medical

sectors drug resistance is on the hike, compelling us to

think of a new antibiotic based herbs instead of synthetic

origin to combat pathogen (Pai et al., 2004; Shah, 2005;

Ibrahim et al., 2011; Obeidat et al., 2012). This slogan

has elevated the demand for the green products such as

Pistia stratiotes; a rich source for new bioactive

compounds. The extract of this plant has showed

antibacterial (Abu Ziada et al., 2008; Fareed et al., 2008;

Sridevi et al., 2010), antifungal (Bhosale et al., 1999;

Haroon, 2006), antiviral (Verma et al., 2008; Shin et al.,

2010; Sohail et al., 2011) and antialgal activities (Li &

Hu, 2005; Yi et al., 2012). Soetan et al., (2006) and Yisa

(2009) reported that flavonoids and phenolic derivatives

of water lettuce affected the function of bacterial cell

membrane as a result inhibited their growth (Trombetta et

al., 2005; Hendrich, 2006). In addition, the extracts

possess some antimicrobial agents whose nature and

number is not clear, however their worth should not be

undermined. Further study should be done to purify and

identify them (Daboor & Amany 2012).

Wound healing potential: Plants have compounds that

help the wound to heal quickly (Kalyon et al., 2009). Pistia

stratiotes contains large amount of compounds that have

antioxidant activity (Zennie & McClure, 1977). For

example sterols from this plant are reported to be

responsible for wound healing property of the plant

(Ayyad, 2002). Tremendous research has been conducted

for the discovery of new antioxidants from herbs to prevent

damage from free radical (Chen et al., 2011; Huang et al.,

2011). In this regard topical application of water lettuce

plant material at the wound increased wound healing

significantly. The healing potential might be due to its

ability to trigger angiogenesis and mitogenesis at the site

(Gupta et al., 2009). The antioxidant property of any

substance is believed to promote wound healing resulting

in skin regeneration. The antioxidant activity of water

lettuce extract is well known, which prevents oxidative

damage and encourages the process of healing. The woundhealing

property of water lettuce is attributed to certain

compounds present in the plant which work alone or in

combination with other compounds in the healing process.

Further study is needed for isolation, characterization and

identification of these bio-compounds (Jha et al., 2012).

Allelopathic effects on terrestrial plants: Annually P.

*stratiotes* produces 10**-**30 tons dry biomass ha-1 (Leng,

1999) while according to Gumbricht (1993) 60**-**110 tons ha-

1 year-1, respectively. Walstad (1999) stated that such a high

biomass production indicates an elevated potential of

allelopathy in the plant; releasing allelochemicals in its

vicinity that prevent other plant to compete with it. Its

phytotoxic effect is dependent on: amount and composition

residues, the environment and management practices (An *et*

*al*., 2000). To date, six allelochemicals have been isolated

from leaf ethyl-ether extract that suppressed the growth of

some phytoplankton and multicellular algae (Aliotta *et al*.,

1991). The allelopathic potential of water lettuce is a best

source for weed management. Currently it is under

screening process (Xuan *et al*., 2005). Screening provides

important basic information on inhibitory effects and their

potential for weed control (Macias *et al*., 2007). Golisz *et*

*al*., (2008) reported that some alellochemicals caused root

cell death indirectly by production of reactive oxygen

species that worked as signaling molecules that changed

hormonal balance during seed germination (Bogatek &

Gniazdowska, 2007). Germination of lettuce in aqueous

extracts of corn residues, caused necrotic root tips and

shorter roots due to damage of meristematic tissue (Chou &

Patrick, 1976). Eucalyptol also inhibits the roots growth of

lettuce seedlings (Romagni *et al*., 2000a). Thus shoot/ root

inhibitors can be utilized in weed management (Monaco *et*

*al., 2002). Bich & Hisashi (2012) reported that Lemna and*

*Pistia’s water and methanolic extracts affected the growth*

*of some dicot and monocot plants. In allelochamicals are*

*specific in action which might suppress one species leaving*

*the other unharmed (Xuan et al., 2005).*

***Miscellaneous uses:*** *In many Asian and African*

*countries and Brazil P. stratiotes leaf extract is used for*

*topical application for various skin diseases and taken*

*orally as laxative and diuretic. It is used for productive*

*cough and asthma along with rose water and sugar. They*

*are also used for treating piles and gonorrhoea. Water*

*lettuce decoction is taken to relieve indigestion, urgency*

*and frequent urination and in baths for reducing*

*hydropsy. The leaves work as appetizers but cause loose*

*motion if overdosed. Water lettuce provides a shelter*

*and food to various types of fishes so their presence is*

*valued for fishermen of Java. Indians and Chinese cook*

*the plant and fed to pigs and ducks, while it is given*

*fresh to rabbits. It can be used as food during food crisis,*

*although it is not palatable. It can be used as a pot herb*

*with sharp taste due to CaC2O4 which causes kidney*

*stone. Due to high potash value it can be used as green*

*manure for potash deficient soils. The high potash*

*content enables it to be used with soap to increase its*

*efficiency. It is grown in aquariums and ponds for*

*aesthetic purposes in some tropical countries but it is*

*thrown in the water bodies in winter where it becomes a*

*noxious weed (Schmelzer et al., 2001).*

**Impacts on the aquatic ecosystem**

**An invasive weed:** Water lettuce found in the irrigation

channels transpires a lot of water and interferes with

paddy crop (Holm *et al*., 1977; Waterhouse, 1993). *P.*

*stratiotes* is an invasive weed in tropical and sub-tropical

conditions, mat forming and rapidly covering the whole

water body, preventing sunlight, affecting water use

efficiency and intended use of water badly. Under the

dense mats available O2 decreases, negatively affecting

biological oxygen demand (BOD) and aquatic plant and

animals consequently lower biodiversity in invaded water

bodies (Langeland & Burks, 2008). Moreover, it blocks

water flow, hinder electricity generation from dams and

harbor dangerous pests (Mbati & Neuenschwander, 2005;

Gangstad & Cardarelli, 1990). The excessive growth of

water lettuce is due to nutrient enrichment, which must be

discouraged to combat this problem (Vaithiyanathan &

Richardson 1999). The dense mates of water lettuce pose

a threat to life of human and livestock by getting

entangled (Anon., 2013).

**Management of *Pistia stratiotes***

**Physical/mechanical control:** Water lettuce can be

managed manually by hand pulling on small scale. In case

of deep water it can be removed by using nets and certain

barriers. However, IN Pakistan this weed is a major

problem in shallow water bodies especially drainage

systems and small ponds. So far there is no use of this

weed. The weeds complete their life cycle and thus add

nutrients to the water bodies which further accelerate the

problem due to availability of nutrients. Mechanically the

weed mat can be cut and the pieces pulled out to the bank

of water body manually or by using machines like tractor

or excavator or boats depending on size of water body.

The use of heavy machines is necessary if it grows mixed

with rooted aquatic weeds (Wade, 1990). Combine

harvester capable of cutting, collecting and bringing the

biomass to the shore can also be used in case of heavy

infestation and on large scale. But this will not ensure the

complete elimination of the plant and re-establishment

may occur, necessitating a long-term control program.

Control measures to be used, should be cost effective and

economical taking into consideration the water body,

intended use of water body and its impact on the fauna

and flora of that area.

**Chemical control:** Water lettuce can effectively be

controlled by sulfonylurea herbicides like chlorsulfuron

(Madin, 1984) and contact herbicides like paraquat and

diquat (Thayer & Haller, 1985) and non-selective

systemic herbicide like glyphosate (Thayer & Haller,

1985; Van *et al*., 1986), a mixture of diquat and triclopyr

(Langeland & Smith, 1993), terbutryn (Vermeulen *et al*.,

1996), 2,4-D (Langeland & Smith, 1993) and endothall

(Rivers, 2002). However chemical control endangers the

environment and should be avoided for a better alternative

approach if possible. As it will suspend the use of water

for a considerable period and disturb the balance of the

aquatic ecosystem by negatively affecting other plants

and animal lives. It may create health hazards for the local

people and birds specially in developing areas. In

indispensable situation special formulation with low

mammalian toxicity should be used as AF101 (Parsons &

Cuthbertson, 1992).

**Biological control:** *Neohydronomus*

affinis is an

excellent biological control agent for water lettuce

(O'Brien & Wibmer, 1989). The weevil (N. affinis) is

native to S. America. DeLoach et al., (1976)

recommended this for various parts of the world

(Harley et al., 1990; Anon., 1995) where it proved

worthy and provided an adequate level of control.

Another insect; the water lettuce moth (Spodoptera

pectinicornis) was screened out and recommended

from Thailand for biological control of Pistia in United

States (Habeck & Thompson, 1994). In an integrated

attempt three different species of weevils were

employed (Argentinorhynchus bruchi, A. breyeri & A.

squamosus) which successfully managed water lettuce

spread under laboratory conditions (Anon., 2001).

Similarly, fungi Ramularia spp. and Sclerotinia

sclerotiorum have also shown potential for managing

water lettuce (Fernandes & Barreto, 2005; Waipara et

al., 2006). Up till now 21 biological agents have been

reported that control P. stratiotes; 5 from Africa, 11

from Asian countries and 9 from Florida (Dray &

Center, 2002). The Larvea of A. drumalis feed on the

roots of water lettuce. *Pistia stratiotes* is a valuable multiuse plant as

well as an invasive aquatic weed in Pakistan. It is one

of the most widely distributed hydrophytes with

cosmopolitan distribution in tropical and sub-tropical

regions. Being a hyper-accumulator it is the cheapest

tool for the phyto-remediation of polluted water bodies

in removing heavy metals and to denature the

antibiotics released into water. *P. stratiotes* contain

alkaloids, glycosides, flavonoids, and steroids, vitamin

A, B and C, proteins, essential amino acids, and

minerals. Its leaves are used in traditional medicine for

treatment of ringworm, syphilis, skin infections, boils,

wounds, fever, tuberculosis and dysentery in many

countries of the world. *P. stratiotes* posses various

biological activities like antibacterial, antioxidant,

bronchodilatory, antitumor, antidermatophytic,

antifungal, diuretic, antiprotease, antidiabetic and

antimicrobial. It is allelopathic causing harmful effects

on other plant through allelochemicals. Favorable

condition and nutrient enrichment in the water bodies

makes it an invasive plant and necessitates its control

through physical, chemical, or biological methods.

Further study on the isolation and identification of the

various bioactive compounds, its role in bioremediation

and different methods of its control is

strongly recommended. As this weed contain nutrients

therefore this weed can be explored to possible use as

fertilizer. Collection, processing and application at

large scale might be difficult but kitchen gardeners can

be motivated to collect this plant and use as fertilizers.

However, the heavy metal accommocation and the

related ill effects need to be investigated.